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EVALUATION OF LIME AS AN AVIAN FEEDING REPELLENT

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Abstract: We evaluated the effectiveness of dolomitic hydrated lime as a feeding deterrent to captive brown-headed cowbirds (*Molothrus ater*) and Canada geese (*Branta canadensis*) during July-September 1995. We conducted 1- and 2-choice tests using grains with caged cowbirds and geese, and applications of lime to turf in dry and slurry form for geese. Lime mixed with millet or whole-kernel corn at 25, 12.5, and 6.25% (g/g) reduced cowbird and goose feeding in 4 day, 2-choice (treated or untreated grain) cage trials. Reductions in total food intake occurred for both species during similar 1-choice tests with lime (25% [g/g]) and millet or corn. Body mass of cowbirds and geese increased or remained constant during 2-choice tests. In contrast, body mass declined for both species during 1-choice tests. Application of lime to enclosed 10- × 10-m-grass plots in powder or slurry form at an application rate of 544 kg/ha also reduced goose feeding on treated plots for 2–3 days. Mean numbers of geese and mean fecal mass on control and treated plots were similar during both turf experiments. No phytotoxicity of grass was observed ≥40 days posttreatment. We recommend additional studies to determine the lower limit of repellency of lime to various bird species and its utility for turf and crop damage reduction.

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Canada goose populations, particularly resident giant Canada geese (*B. c. maxima*) have increased throughout many portions of North America in recent years. For example, the giant Canada goose population is doubling in Ontario every 5 years (Ankney 1996). Canada goose numbers have increased 148%, from 745,000 to 1,850,000 between 1980 and 1989 (Babcock et al. 1990). Availability of waste grain and open water during winter have contributed to these increases (Ankney 1996).

There are numerous situations where it is desirable to discourage birds from feeding. For example, Canada goose depredation on agricultural crops and turf has caused severe localized economic loss (Hunt 1984, Kahl and Samson 1984, Conover and Chasko 1985, Conover 1988). In addition, high concentrations of goose feces in urban settings (e.g., golf courses, parks) has resulted in reduced aesthetic and recreational value (Conover and Chasko 1985).

Although many blackbird (Icteridae) populations have remained constant during the last 3 decades (Peterjohn et al. 1994), this group of birds can cause substantial economic loss to a variety of agricultural crops (Heisterberg 1983, Hothem et al. 1988, Decker et al. 1990, Dolbeer 1990). For example, Dolbeer (1980) reported a 4- to 7-million dollar annual loss of corn from blackbird damage in Ohio during 1977–79. In 1981, depredation by blackbirds on ripening field corn in the United States was estimated at 272,154 metric tons with a value of $31,000,000 (Besser and Brady 1986). Damage to sprouting crops by waterfowl, cranes, and crows also occurs (Johnson 1994, Cleary 1994, Dolbeer et al. 1994).

Although various mechanical frightening and harassment devices have been employed in efforts to alleviate these conflicts (Marsh et al. 1991, Cleary 1994, Dolbeer et al. 1994), only one repellent, methyl anthranilate, currently is registered with the U.S. Environmental Protection Agency (Dolbeer et al. 1993, Belant et al. 1995, Cummings et al. 1995) for use in a few problem situations. Repellents are essential as part of an integrated management program to

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alleviate conflicts caused by geese, blackbirds, and other federally-protected birds. One compound that has potential value as a repellent is lime. A lime-sulphur compound has been used as a repellent for jackrabbits (Knight 1994). More recently, Dolbeer and Ickes (1994) demonstrated feeding aversion by captive red-winged blackbirds (*Agelaius phoeniceus*) to wild rice treated with Portland cement and plaster of Paris, which contained large proportions of lime or calcium (Ca) sulfate. They documented a 95% reduction in feeding on wild rice treated with these materials during 2-choice tests. Furthermore, lime is an inexpensive and safe compound that is used routinely in agricultural practices (e.g., to increase pH of soil or Ca and magnesium [Mg] concentrations). Our objective was to evaluate the effectiveness of lime as a feeding repellent for Canada geese and brown-headed cowbirds using aviary and controlled field experiments.

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METHODS

For all experiments, we used dolomitic hydrated lime (hereafter referred to as lime) (GenLime Group, L.P., Genoa, Oh.), primarily comprised of CaMg hydroxide and Ca hydroxide Mg oxide. This product has a pH of 11.7 and contained minimum concentrations of 30% Ca, 16% Mg, 42% Ca oxide, and 27% Mg oxide. Particle size is variable, with 99 and 67% (by mass) passing through 20 and 100 mesh. This lime commonly is used in turf, garden, and agricultural practices.

Adult male brown-headed cowbirds (mean mass = 45 g) were captured in decoy traps in northern Ohio during July 1995 and transported to an outdoor aviary in Erie County. Cowbirds were held in groups in 2.5- × 2.5- × 2.0-m holding cages in the outdoor aviary before the experiments. Experimentally-naive birds were used for each test and were released after completion of the experiment.

Flightless Canada geese (mean mass = 2.95 kg) of undetermined sex were captured during molt in northern Ohio during June 1995 and transported to a 2-ha fenced pond in Erie County. Grass and shade were available along the perimeter of the pond. Primaries from 1 wing were plucked from geese before being released into this pond. Cracked- or whole-kernel corn was provided as a food supplement. A 0.4-ha holding area adjacent to the pond was used to separate experimental from non-experimental geese. This holding area contained grass, shade, and included about 20 m^2 of the pond. Geese maintained in this area also were provided corn. A 25-m fenced chute connected the holding area to the test site that consisted of 4 10- × 21-m pens constructed of 1.5-m-high fence in a grass area. A 1-m-wide buffer of grass was delineated with spray paint such that each pen consisted of 2 10- × 10-m plots (1 each treatment and control). Two 0.5-m-diameter pans of water were located within each buffer area. Pens were mowed to a height of 5 cm about every 7 days. A rain gauge was placed at the test site to monitor precipitation. Experimentally-naive geese were used for each test and were released after completion of the experiments.

Cage Tests

Experiment 1.—Sixteen pairs of brown-headed cowbirds were selected randomly, banded, and placed in 1.0- × 1.5- × 0.5-m cages containing water, grit, and mixed bird seed (Woronecki et al. 1986). We established treatment groups of 8 birds (2 birds in each of 4 cages) by systematically assigning treatments to cages. For 4 days immediately preceding the experiment, birds were provided 2 cups (0.1 L) containing millet. Each cup was attached to a 24-cm-diameter pan to catch spillage.

On day 1 of the experiment, cowbirds were weighed at 0900 hours and 2 food cups were placed in each cage. One cup contained 25.0 g of millet and the other 25.0 g of millet mixed with 25.0, 12.5, or 6.25% lime (g/g). All other food, but not water or grit, was removed. For the next 4 days, cups were removed at 0900 hours and replaced with fresh millet or millet/

lime mixtures. Positions of the cups were randomized each day. The contents of removed cups, including spillage, were weighed to determine consumption. Final 24-hour consumption was adjusted for moisture gain or loss based on weight changes of control cups of millet and millet with lime placed adjacent to the cages. Cowbirds were reweighed at 0900 hours on day 4. A similar 1-choice test was conducted simultaneous to the 2-choice tests except that both food cups contained 25.0 g millet mixed with 25% lime (g/g). We conducted 4 replicates of each of the 4 tests.

We compared consumption of food using a 3-factor repeated measures analysis of variance (ANOVA; SAS Inst. Inc. 1988). Tukey tests were used to isolate differences ($P < 0.05$) among means. We compared changes in body mass of cowbirds for each test using paired t-tests. All means are reported with ± 1 standard error.

Experiment 2.—Sixteen Canada geese were selected randomly from the holding area and placed individually in 2.5- × 2.5- × 2.0-m outdoor holding cages set on a paved surface. We established treatment groups of 4 birds (4 cages) by systematically assigning treatments to cages. Geese were provided whole corn and water ad libitum for 4 days before testing; no alternative food was available.

On day 1 of the test, geese were weighed at 0900 hours and 2 food pans (8 L) were placed in each cage. For 2-choice tests, 1 pan contained 1.0 kg whole-kernel corn and the other 1.0 kg corn mixed with 25.0, 12.5, or 6.25% lime (g/g). For the 1-choice test, each food tray contained 1.0 kg of corn mixed with 25% lime (g/g). All other food, but not water, was removed. Remaining procedures, number of replications, and statistical analyses were identical to those described for the cage experiment with cowbirds.

Turf Tests

Experiment 1.—For 7 consecutive days before testing, 24 geese were herded from the holding area to the pen test site. Six geese were placed in each pen at 0900 hours and allowed to graze until 1600 hours when they were herded back to the holding area. Numbered neck bands were attached to geese to ensure the same individuals were placed in the same pens on consecutive days.

On the day before testing, grass in the pens was mowed to a height of 5 cm and 1 plot in each pen was selected randomly and treated with lime with a push-operated rotary spreader at a rate of 544 kg/ha. To ensure even coverage, we dispensed lime by operating the spreader in 2 series of perpendicular transects over each entire plot. Grass in treated plots was gray-white in color. Remaining plots served as controls.

Two individuals positioned in separate vehicles 10–15 m from the pens monitored goose activity. Vehicles had been positioned near the pens frequently during pretreatment to ensure their presence did not modify goose behavior. Observations occurred daily for 60 minutes, beginning immediately after geese were released into the pens (0900 hr). Each observer watched geese in 2 pens, alternating observations between pens every 60 seconds (daily total of 30 min/pen). During each 60-second interval, observers recorded the number of geese observed initially in each plot, and the total number of bill contacts with grass in each plot.

To estimate fecal mass on each plot, we established 2 1-m-wide transects between diagonally opposing corners. We collected feces daily at 1600 hours from each plot during the treatment period. Feces were then placed in a drying room at 38 C for 48 hours before weighing. Fecal mass was converted to g/plot for each plot by day of collection before analysis.

Mean numbers of geese observed, mean numbers of bill contacts, and mean mass of fecal material on each plot were determined and compared between treatments with randomized block (pens) ANOVA with repeated measures (days) (SAS Inst. Inc. 1988). All means are reported with ± 1 standard error.

Experiment 2.—We began herding 24 experimentally-naive geese into pens 40 days after the conclusion of experiment 1. Experiment 2 was conducted identically to experiment 1 except that treated plots were sprayed with lime in slurry form at an application rate of 544 kg/ha. The slurry was a 1:20 (g/g) lime-water mixture with 0.001% (vol/vol) binding agent (Exhalt 800, Pbi/Gordon Corp., Kansas City, Kans.).

RESULTS

Cage Tests

Experiment 1.—Overall, brown-headed cowbirds consumed more ($F = 4{,}354.43$; 1, 12 df; $P < 0.01$) untreated millet than treated millet

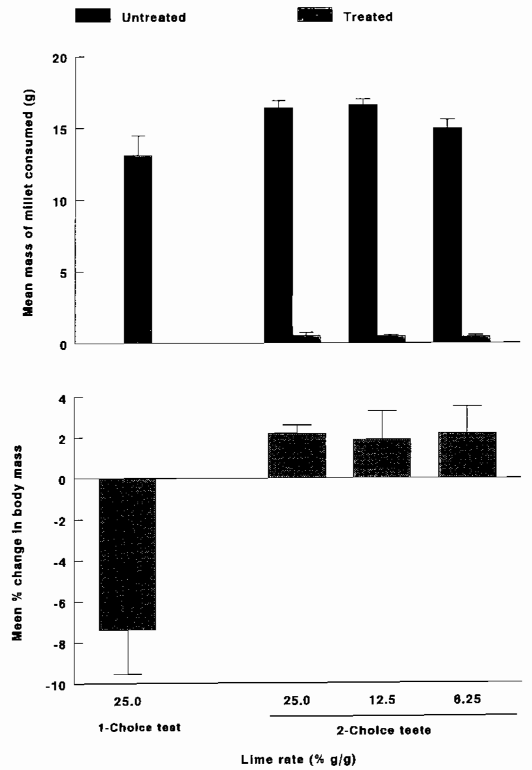

Fig. 1. Mean daily (24-hr) consumption of lime-treated and untreated millet by pairs of captive male brown-headed cowbirds and mean percent change in individual body mass during 4-day, 1- and 2-choice tests, Erie County, Ohio, July 1995. Capped vertical bars represent 1 standard error.

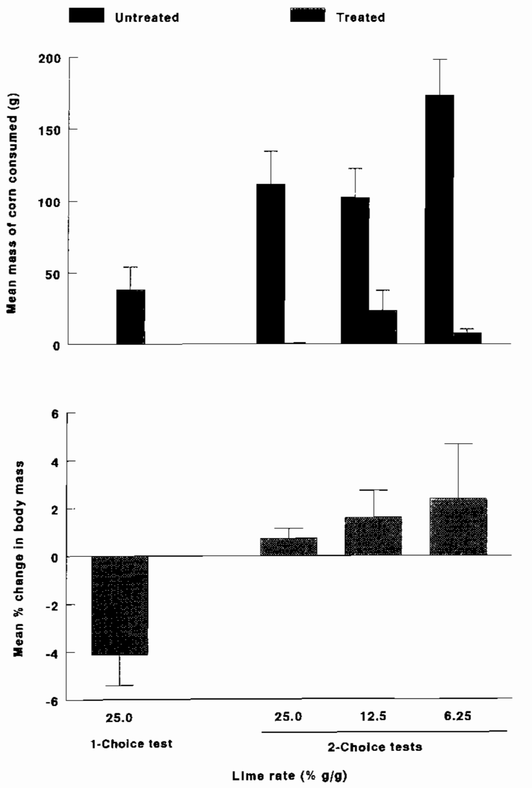

Fig. 2. Mean daily (24-hr) consumption of lime-treated and untreated corn by individual captive Canada geese and mean percent change in body mass during 4-day, 1- and 2-choice tests, Erie County, Ohio, August-September 1995. Capped vertical bars represent 1 standard error.

(Fig. 1). For 2-choice groups, there was a ≥97% reduction in consumption of lime-treated millet compared to consumption of untreated millet. Total mean daily consumption of millet by cowbirds in the 1-choice group (13.12 ± 1.36 g) was less (F = 27.79; 3, 12 df; $P < 0.01$) than total mean daily consumption of millet by cowbirds in 2-choice groups (≥16.89 ± 2.90 g). Total mean daily consumption was similar ($P > 0.05$) among the 3 2-choice groups.

For 1- and 2-choice groups, consumption of treated millet increased (F = 12.80; 3, 36 df; $P < 0.01$) overall from days 1–3, then declined on day 4. The group-day interaction (F = 5.64; 9, 36 df; $P < 0.01$) reflected increased consumption of millet on days 3–4 by cowbirds in the 1-choice group, which equalled total consumption of millet by cowbirds in the 2-choice groups.

Mean body mass of cowbirds in the 1-choice group decreased (t = 3.43, 8 df, P = 0.01) 7.4% during the 4-day test (Fig. 1). In contrast, mean body mass of cowbirds remained constant (t = 1.37 and 1.67, 8 df, P = 0.21 and 0.14) in 2-choice groups with 12.5 and 6.25% lime and increased (t = 5.29, 8 df, $P < 0.01$) 2.2% in the 2-choice group with 25% lime.

Experiment 2.—Canada geese consumed more (F = 6.05; 1, 12 df; $P < 0.01$) untreated corn than treated corn (Fig. 2). For 2-choice groups, there was a ≥77% reduction in consumption of lime-treated corn compared to consumption of untreated corn. Total mean daily consumption of corn by geese in the 1-choice group (38.0 ± 16.0 g) was less (F = 27.79; 3, 12 df; $P < 0.01$) than total mean daily consumption of corn by geese in 2-choice groups (≥111.5 ± 30.1 g). Total mean consumption of corn was similar ($P > 0.05$) among the 3 2-choice groups.

Consumption of treated corn increased (F = 6.05; 3, 36 df; $P < 0.01$) overall from days 1–3, then declined on day 4. There was no interaction of day with treatment (F = 0.59; 3, 36 df;

P = 0.63) or test group (F = 1.45; 9, 36 df; P = 0.19). There was a 3-way interaction of day, treatment, and test group, primarily a consequence of geese eating no treated corn in the 1-choice test on day 2.

Mean body mass of geese in the 1-choice group decreased (t = 3.22, 4 df, $P < 0.05$) 4.1% during the 4-day test. In contrast, mean body mass of geese remained constant (t = 1.06–1.73, 4 df, $P > 0.18$) during the 3 2-choice tests.

Turf Tests

Experiment 1.—There was a treatment by day interaction (F = 2.48; 6, 36 df; P = 0.04) for bill contacts. Using post hoc tests on the interaction means at an experimentwise error rate of 0.05, we determined that the number of bill contacts with grass on lime-treated plots was less than the number on control plots on days 1–3 (Fig. 3). There were no differences ($P >$ 0.05) in bill contacts on treated and control plots after day 3. There was a day effect (F = 3.34; 6, 36 df; P = 0.01) for bill contacts, with an overall increased number of contacts observed on day 7.

There was no effect of treatment on goose presence (F = 14.07; 1, 6 df; P = 0.50) or amount of fecal mass collected (F = 0.76; 1, 6 df; P = 0.42). There were also no day effects or day and treatment interactions for goose presence (F = 0.19 and 0.53; 6, 36 df; P = 0.83 and 0.61) or fecal mass (F = 2.88 and 0.98; 6, 36 df; P = 0.09 and 0.41).

On several occasions we observed geese immediately drinking water or shaking their heads laterally after a series of bill contacts with lime-treated grass. These behaviors were not observed for geese feeding in control plots.

We recorded 0.0, 0.0, 0.0, 0.1, 2, 15.5, and 1 mm rain on days 1–7. Rainfall created areas of grass on the treated plots with visibly reduced levels of lime; treated plots appeared visually similar to control plots by day 7. No phytotoxicity of grass was observed for 56 days posttreatment.

Experiment 2.—One goose appeared to have contracted pneumonia and was removed from the experiment on day 5 to recover in the holding area. A second goose from a different pen escaped before observations on day 7. Thus bill contacts, goose presence, and fecal mass by plot for geese in these 2 pens were weighted proportionally on days when these geese were absent, with data from 5 of 6 geese remaining in each of the 2 pens.

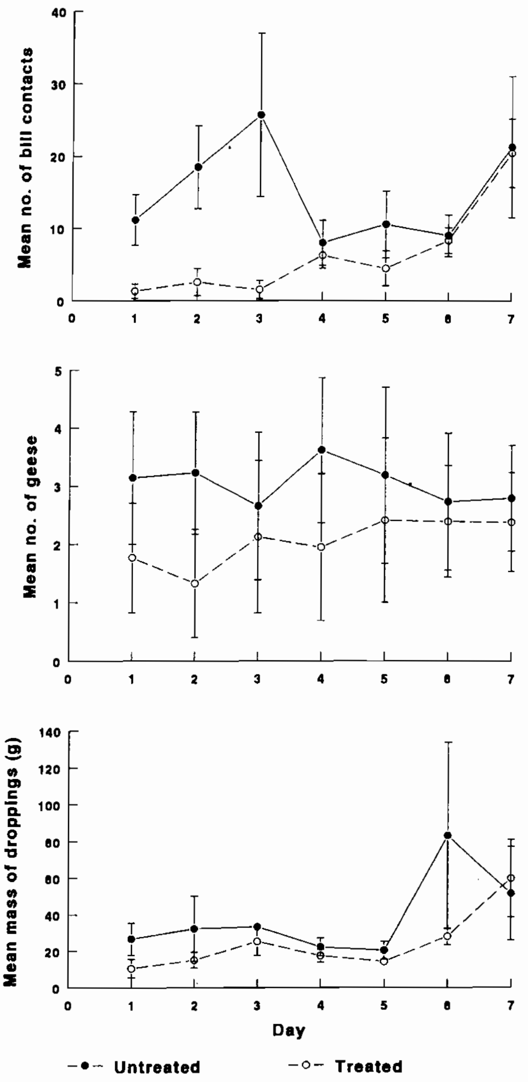

Fig. 3. Mean number of bill contacts/6 Canada geese/minute, number of geese/observation, and fecal mass/0.01 ha/7 hours on grass plots treated with dolomitic hydrated lime in powder form at an application rate of 544 kg/ha, and on control plots, Erie County, Ohio, July 1995. Capped vertical bars represent 1 standard error.

We observed more (F = 35.60; 1, 6 df; $P <$ 0.01) bill contacts on control plots (21.3 ± 2.2) than on treated plots (9.7 ± 1.4) overall. Using post hoc tests we determined that the mean number of bill contacts with grass on treated plots was less than the mean number of bill contacts on control plots on days 2–3 (Fig. 4). There were no differences ($P >$ 0.05) in the mean number of bill contacts on treated and

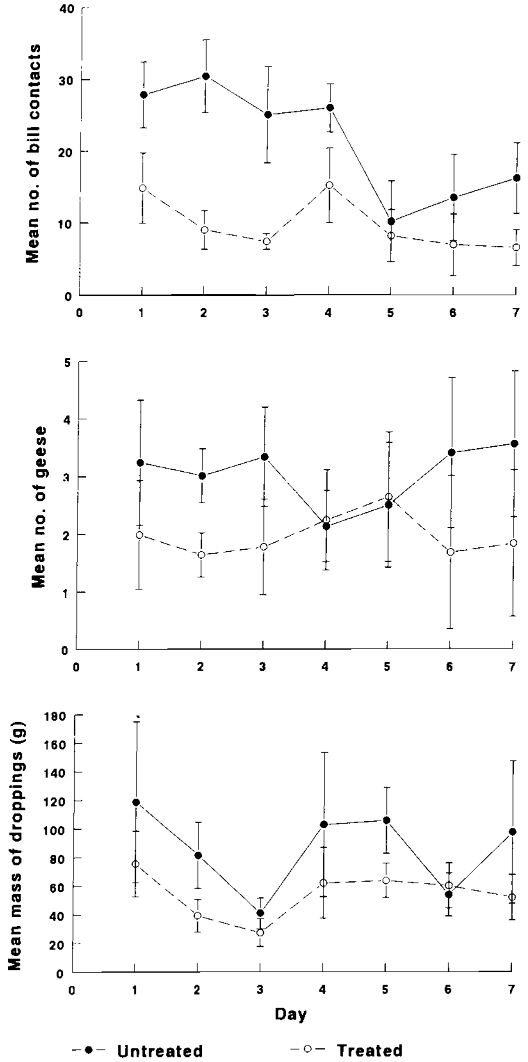

Fig. 4. Mean number of bill contacts/6 Canada geese/minute, number of geese/observation, and fecal mass/0.01 ha/7 hours on grass plots treated with dolomitic hydrated lime in slurry form at an application rate of 544 kg/ha, and on control plots, Erie County, Ohio, September 1995. Capped vertical bars represent 1 standard error.

control plots on days 1 and 4–7. There was also a day effect ($F = 2.58$; 6, 36 df; $P = 0.04$) for bill contacts, with increased numbers of bill contacts observed overall on days 1–2 and 4.

There was no effect of treatment on mean numbers of geese observed ($F = 0.77$; 1, 6 df; $P = 0.42$) or fecal mass collected ($F = 1.52$; 1, 6 df; $P = 0.26$). There were also no day effects or day and treatment interactions for goose presence ($F = 0.19$ and 1.02; 6, 36 df; $P = 0.94$ and 0.42) or fecal mass ($F = 1.53$ and 0.34; 6, 36 df; $P = 0.20$ and 0.91).

As in experiment 1, we observed geese immediately drinking water or shaking their heads laterally after a series of bill contacts with lime-treated grass. These behaviors were observed less frequently for geese feeding in control plots.

We recorded 0.0 and 2.5 mm rain on days 1–6 and 7. Lime remained visible on treated plots ≥7 days posttreatment. No phytotoxicity of grass was observed for 40 days posttreatment.

DISCUSSION

Lime was equally repellent to cowbirds or geese when applied to food at rates of 6.25–25.0% (g/g), with observed reductions in consumption of lime-treated feed ≥77% that of untreated feed during 2-choice tests. In addition, consumption was reduced for both species when only lime-treated food was available, resulting in significant loss of body mass. Using red-winged blackbirds in 2-choice tests, Dolbeer and Ickes (1994) found similar reductions in consumption of wild rice (*Zizania aquatica*) treated with Portland cement or plaster of Paris (50% g/g), which contained large proportions of lime or Ca sulfate. In contrast to this study, however, they found that consumption of treated wild rice without alternative food available was equal to total consumption when untreated rice was available. Although the mechanism causing repellency in these compounds is unknown, that lime is more repellent than Portland cement or plaster of Paris may be related to its smaller particle size. Lime has a desiccating effect and its greater surface area per unit volume could increase exposure to birds and consequently enhance repellency. Also, as shown for quartz sand and activated charcoal (Mason and Clark 1994), avoidance of lime could be related to its oral sensory texture. There may be general aversion by birds to food treated with small particulates (Mason and Clark 1995).

Lime may induce feeding aversion by having a caustic effect on mucous linings of the mouth or by altering the pH of gastrointestinal fluids. Lime frequently is used in turf management or agriculture to increase pH of soil. This increase toward alkalinity could have caused gastric malaise and/or affected digestion. The white-gray color of lime also may have provided visual aversion or learned association that aided in repellency. Observational learning can increase the effectiveness of repellent compounds (Shumake et al. 1977, Mason and Reidinger 1983). Initial aversion by numerous bird species to food that was dyed various colors has been documented (Kalmbach and Welch 1946. Pank 1976, Mason and Reidinger 1983, Mastrota and Mench 1995); however, habituation to visual cues may occur rapidly (Mastrota and Mench 1994).

There are several potential explanations why geese were repelled from grass by the lime powder but not the lime slurry on day 1. For example, powdered lime likely was more concentrated at the upper portion of turf whereas, because of pressure application, the lime slurry was distributed more evenly vertically within the grass. Thus, geese initially may have ingested more lime/bill contact during the experiment with powdered lime. Also, particles of powdered lime may have been inhaled during grazing, causing nasal irritation and potentially increasing repellency overall.

The ineffectiveness of lime to reduce goose grazing on turf after day 3 of each trial may have been a consequence of rapid growth of the grass. Several days after treatment, we observed noticeable amounts of untreated grass at the base of previously treated leaves. Thus, geese may have been selecting for the untreated portion of the treated grass. This increase in consumption also may have been accentuated by heavy rain observed during the second turf trial.

Reductions in the numbers of geese and fecal material observed in treated plots did not occur, even when reductions in grazing rates on treated turf did occur. In studies evaluating goose feeding repellents (Cummings et al. 1995), reductions in numbers of geese observed and amounts of fecal material in areas where repellents are applied are assumed to reflect reductions in consumption. That reductions in goose presence and fecal material in treated plots did not occur in our study was likely an artifact of the geese being held in pens.

Phytotoxicity of grass was not observed during this study $\geq$40 days posttreatment with application rates of 544 kg/ha. Thus, phytotoxicity to agricultural crops, at least monocots, probably would not occur at or below this application rate. This application rate is considerably less than currently used in northern Ohio, where application rates of about 4,500 kg/ha are applied to agricultural fields with acidic soil during tillage at 3–5 year intervals to increase soil pH (B. Hudson, Oh. Agric. Ext. Off., pers. commun.).

MANAGEMENT IMPLICATIONS

The retail cost of lime at the application rate used on turf was $96/ha. Costs undoubtedly would be reduced if lime was purchased in bulk. Lime may compare favorably to methyl anthranilate (MA), which costs $270/ha when applied in solution to turf at the manufacturer recommended rate (Belant et al. 1996). Canada goose use of MA-treated grass in enclosures was reduced for 4 days (Cummings et al. 1995). In a turf trial similar to those used in this study, Belant et al. (1996) found that Canada goose consumption of MA-treated grass was not reduced, even when MA was applied at 3 times the manufacturer recommended rate. However, because of the gray-white color of grass after application, lime may not be suitable in some turf management situations (e.g., golf courses).

Several advantages of lime over other potential feeding repellents include low cost, availability, and ease of application. As lime already is used frequently in turf management and agricultural practices, approval for registration as an avian repellent likely would be simplified relative to other compounds. Additional evaluations of lime to determine mode of action and minimum effective concentrations on turf and agricultural crops are planned.

As numbers of Canada geese and other geese continue to increase in rural and urban areas, so too will agricultural losses and nuisance situations. Although lethal control has been stated as the most effective means for resolving this problem at a broad scale (Ankney 1996), continued research on novel approaches for nonlethal techniques to reduce damage caused by geese and other birds is necessary to maximize the overall effectiveness of control programs, especially for localized problems.

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